3

A PRELIMINARY ANALYSIS
OF NINE LATERAL HEAD IMPACT TESTS

David P. Roberts
Calspan Corp.
Advanced Technology Center
Buffalo, NY 14225

October 11, 1985

Presented at:

International Workshop on Human Subjects
for Biomechanical Research
Thirteenth Annual Workshop
Washington, DC

Nine lateral head impacts have been performed at Calspan Advanced Technology Center using a linear impactor. The head impacts were performed with the centerline of the impactor face aligned at the level of the external auditory meatus of the subjects' left side. The heads of the subjects were supported by a chin strap that "breaks away" upon impact. In each case the arterial pressurization of the brain was performed.

Pressurization of the Head

Ligation of both vertebral arteries was accomplished by making an incision in the skin overlying the clavicle bilaterally. The subclavius muscle and clavipectoral fascia were cut and the subclavian vein and branches of the brachial plexus were reflected.

A Foley catheter was then inserted into both internal carotids and the ligation of both external carotids was performed. The external carotids were isolated (usually at C4) using the same neck incisions previously noted. In this procedure, care was taken to avoid damaging the middle and superior thyroid veins as well as the common facial vein.

The vessels were then ligated at their origin and if necessary the ascending pharyngeal arteries were included. Upon ligation of the external carotids, a Foley catheter was then inserted into each internal carotid artery and passed superiorly to within one inch of the opening of the carotid canal. They were then held in place by inflating the balloon.

Transducers were connected to each system and pressurization was accomplished by using Dianeal dyed with India ink. All of the incisions were either sutured or closed with wound clips.

In all cases attempts were made to identify the subjects' in-vivo systolic blood pressures so correct pressurization levels of the brain could be accomplished. This measure helped prevent injuries due to pressurization alone.

Table 1 lists the impactor and subject characteristics for each of the nine lateral head impacts with the Calman* listed in ascending order of injuries. Table 2 lists the subjects and associated injuries also in ascending order.

CII

A rating scale, the Cumulative Injury Index (CII) was developed for use in comparing injuries among subjects. The equation for calculating the CII along with two example are shown below.

$$\text{CII} = \text{AIS \#1} + \left[\frac{\text{AIS \#2}}{\text{AIS \#1}}\left(\frac{1}{2}\right)^1\right] + \left[\frac{\text{AIS \#3}}{\text{AIS \#1}}\left(\frac{1}{2}\right)^2\right] + \left[\frac{\text{AIS \#4}}{\text{AIS \#1}}\left(\frac{1}{2}\right)^3\right] + \ldots$$

Example 1
AIS injuries: AIS4, AIS4, AIS4, AIS4

$$4 + \left[\frac{4}{4}\left(\frac{1}{2}\right)^1\right] + \left[\frac{4}{4}\left(\frac{1}{2}\right)^2\right] + \left[\frac{4}{4}\left(\frac{1}{2}\right)^3\right] = 4.875$$

Example 2
AIS injuries: AIS2, AIS2, AIS2, AIS2

$$2 + \left[\frac{2}{2}\left(\frac{1}{2}\right)^1\right] + \left[\frac{2}{2}\left(\frac{1}{2}\right)^2\right] + \left[\frac{2}{2}\left(\frac{1}{2}\right)^3\right] = 2.875$$

From these examples it can be seen that the CII weights the AIS values in a similar manner regardless of the AIS level.

*Calman is a generic term used to identify a human cadaver used in research at Calspan. The number is a series number, i.e., Calman 25 (CM25) is the 25th human cadaver used at Calspan.

Table 1

SUMMARY OF LATERAL HEAD IMPACTS

NO.	CALMAN	SEX	AGE	HEIGHT (IN.)	WEIGHT (LBS.)	IMPACTOR CHARACTERISTICS CONFIGURATION	WEIGHT (LBS.)	VELOCITY (FT/SEC.)
1	32	female	60	65.5	126	6.75"x8" flat plate	58.3	7.3
2	42	male	60	68.0	190	8"x10" flat plate	59.0	10.6
3	34	male	55	71.0	141	6" circle flat plate	52.3	11.0
4	25	male	55	72.0	188	8"x10" flat plate	55.8	14.0
5	33	female	70	67.0	131	6.75"x8" flat plate	58.3	12.9
6	29	male	71	67.0	151	8"x10" flat plate	55.8	13.2
7	30	male	66	69.0	185	8"x10" flat plate	55.8	13.1
8	35	male	69	69.0	150	6" circle flat plate	52.3	13.1
9	31	male	57	67.5	161	8"x10" flat plate	59.0	13.2

<u>Mean Values</u>

	Age	Height	Weight
male	61.9	69.1	166.6
female	65.0	66.3	128.5

Table 2

LATERAL HEAD IMPACT INJURIES

Number	Calman	(1) HIC	(2) CII	AIS with Injuries (3) 1	2	3	4
1	32	206	0.00	0 - No Damage			
2	42	888	0.00	0 - No Damage			
3	34	549	3.00	3 - B CT (R)			
4	25	1021	3.00	3 - B CT (R)			
5	33	658	3.56	3 - B CT (R)	3 - B CT (L)		
6	29	1290	3.56	3 - B CT (R)	3 - S F (L)		
7	30	1306	3.56	3 - B CT (R)	3 - B CT (L)		
8	35	1284	3.78	3 - B CT (R)	3 - B CT (L)	3 - S F (I)	
9	31	1545	3.84	3 - B CT (R)	3 - B CT (RI)	3 - B CT (L)	3 - B CT (LI)

(1) HIC = Head Injury Criteria
(2) CII = Cumulative Injury Index
(3) B = Brain, S = Skull, CT = Contusion, F = Fracture
R = Right, L = Left, RI = Right Inferior, LI = Left Inferior, I = Inferior

The CII represents all of the injuries and not merely the highest AIS injury. It must be emphasized that the CII does not reinterpret the AIS values to give a new AIS but incorporates all of the subjects' injuries into a value that can be used in a rating scale. A CII value of 2.85, for example, tells the analyst that the highest AIS value was 2 and there were other injuries associated with this subject (to give the additional 0.85 value). When the CII is compared to another subject's CII the analyst can tell if the subject had more than one injury and which subject may have had more extensive injuries. It does not, however, give any information about how severe the injuries were or which subject has a higher probability of death.

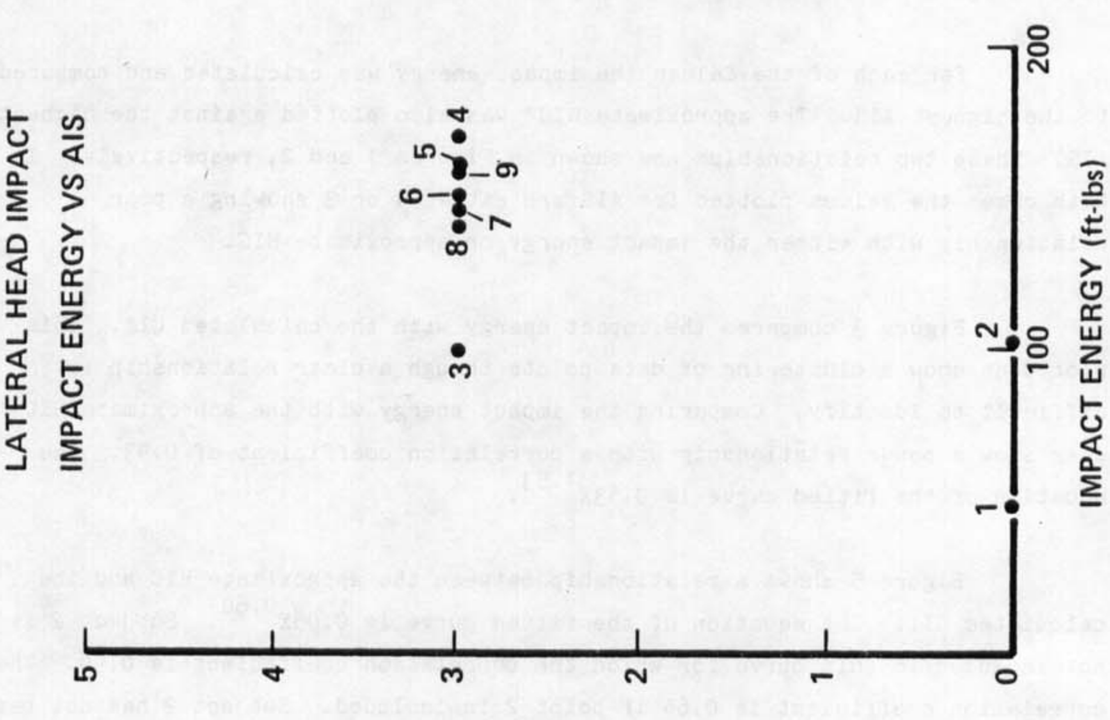
For each of the Calman the impact energy was calculated and compared to the highest AIS. The approximate HIC* was also plotted against the highest AIS. These two relationships are shown in Figures 1 and 2, respectively. In both cases the values plotted for AIS are either 1 or 3 showing a poor relationship with either the impact energy or approximate HIC.

Figure 3 compares the impact energy with the calculated CII. This plot does show a clustering of data points though a clear relationship is difficult to identify. Comparing the impact energy with the approximate HIC does show a power relationship with a correlation coefficient of 0.93. The equation of the fitted curve is $0.53X^{1.53}$.

Figure 5 shows a relationship between the approximate HIC and the calculated CII. The equation of the fitted curve is $0.05X^{0.60}$. Subject 2 is not included in this curve for which the correlation coefficient is 0.90. The correlation coefficient is 0.66 if point 2 is included. Subject 2 has not been included in this curve because the approximate HIC value appears erroneous due to the lack of associated injuries with a HIC of 888.

*The HIC is calculated using a nine accelerometer unit attached to the apex of the subjects' head. Stereotaxic measurements of this unit have been made for each subject but have not been incorporated into the presented HIC calculations, and therefore this is an approixmate HIC value.

Figure 1



LATERAL HEAD IMPACT
IMPACT ENERGY VS AIS
AIS (HIGHEST)
IMPACT ENERGY (ft-lbs)
0
1
2
3
4
5
100
200
1
2
3
4
5
6
7
8
9

Figure 2

LATERAL HEAD IMPACT
HIC VS AIS

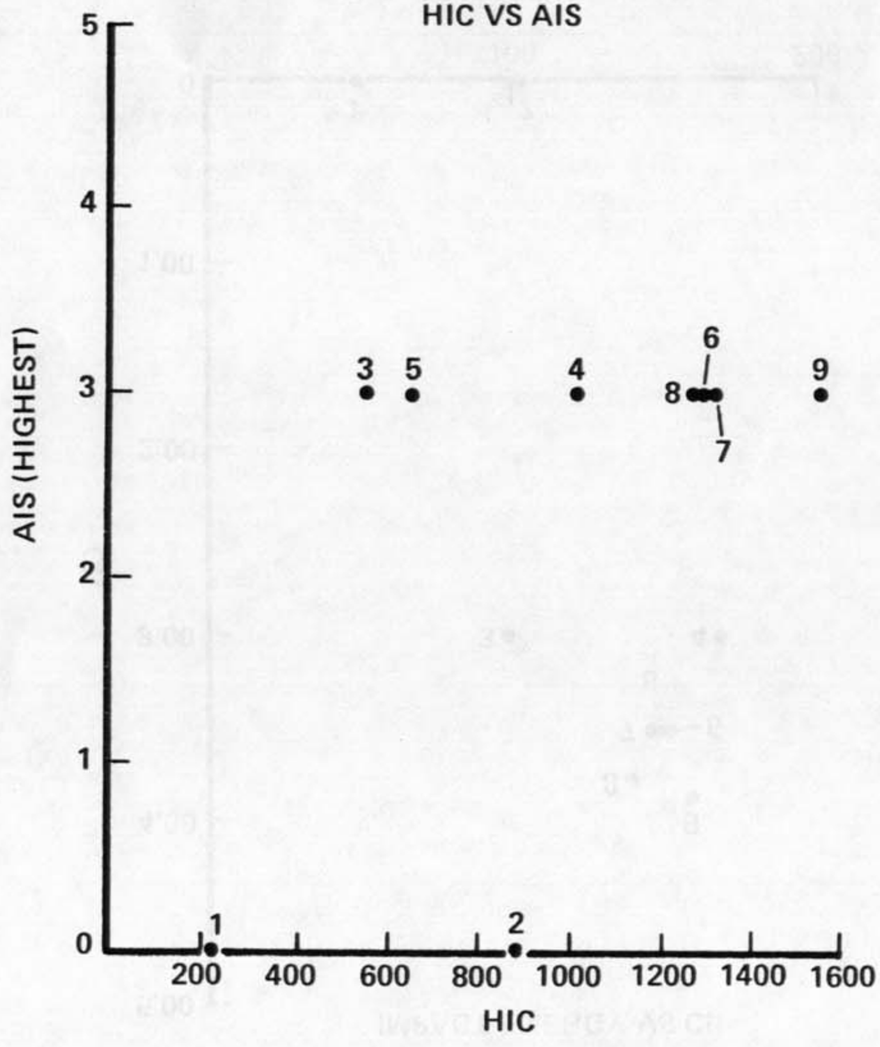


Figure 3

LATERAL HEAD IMPACT

IMPACT ENERGY VS CII

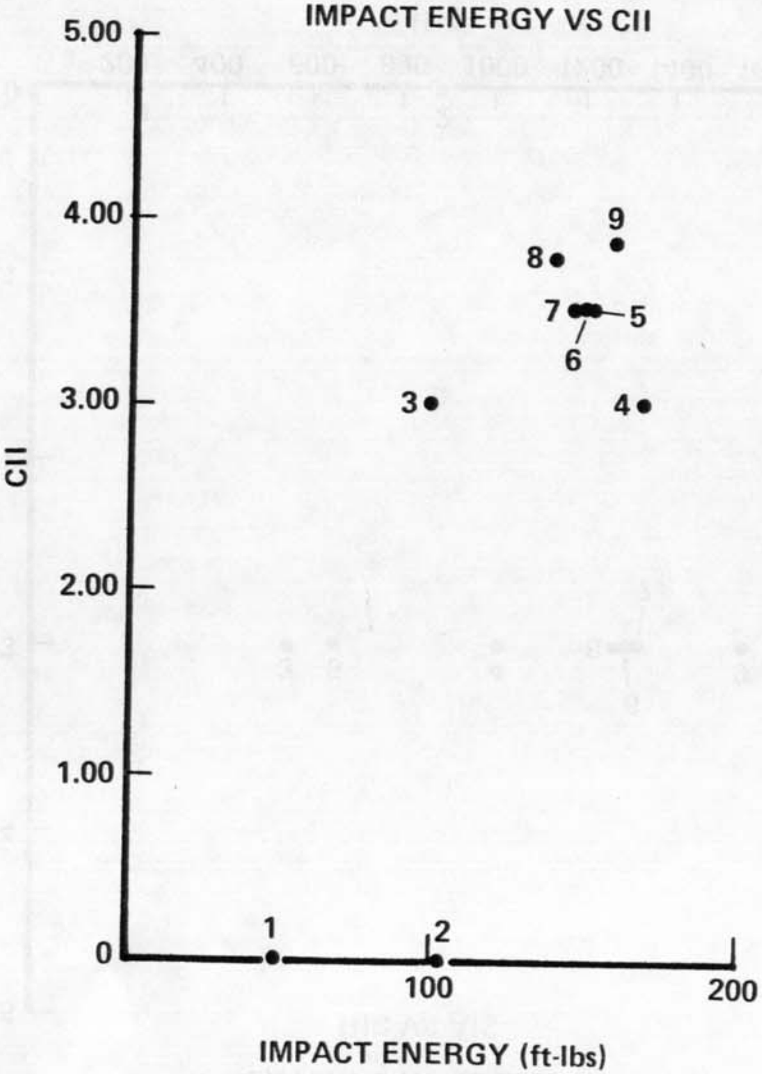


Figure 4

LATERAL HEAD IMPACT
IMPACT ENERGY VS HIC

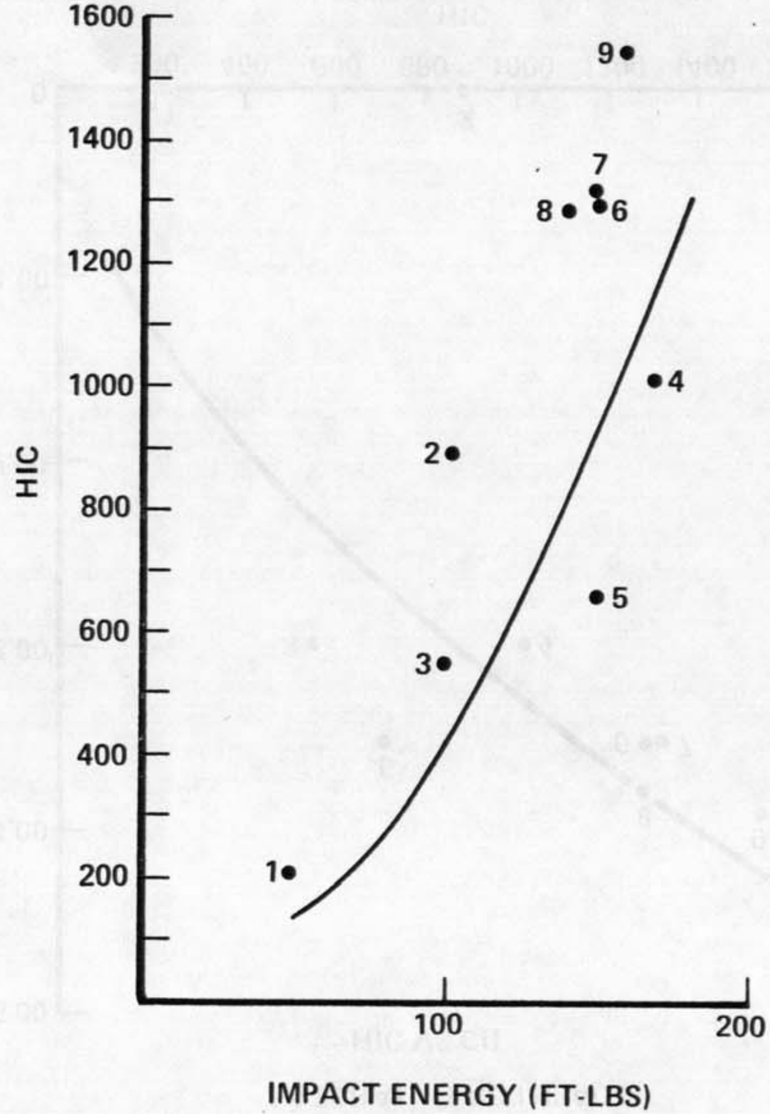
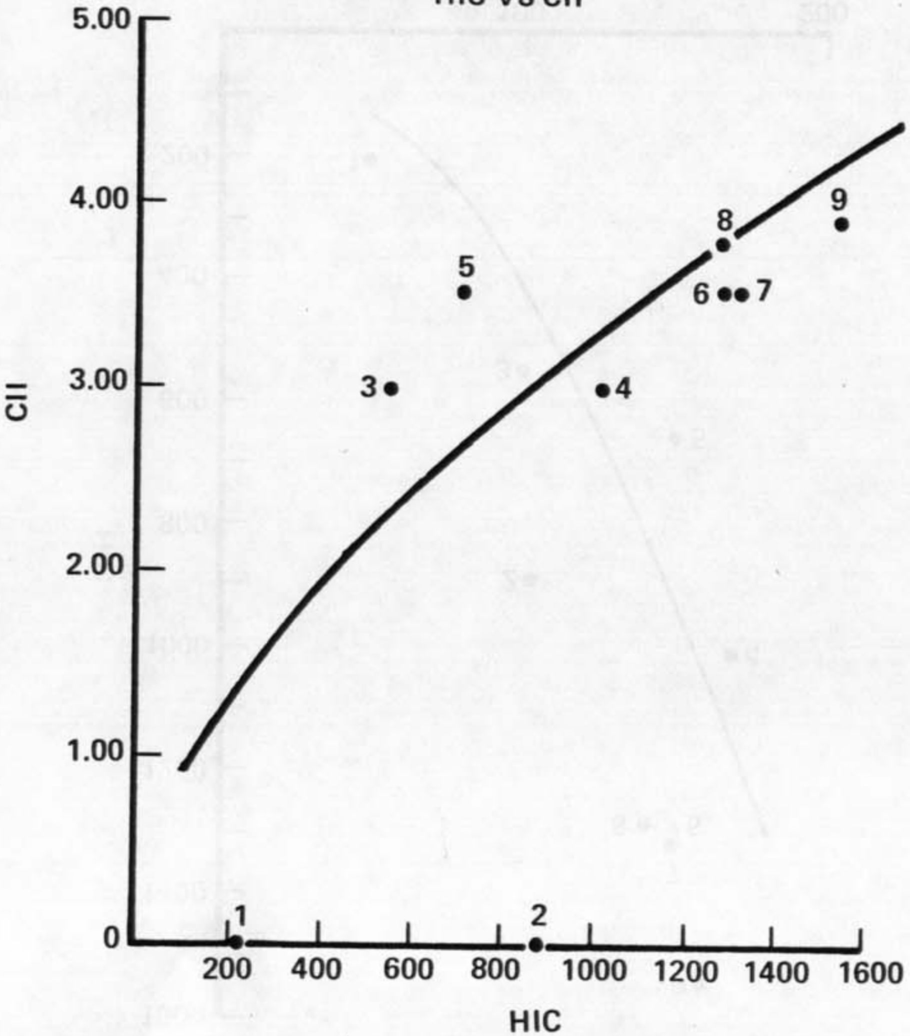


Figure 5

LATERAL HEAD IMPACT

HIC VS CII



Using the curves generated from Figures 4 and 5 injury levels can be predicted based on the calculated impact energy. This must be tested, however, with a larger data base of differing impact energies, HIC and CII levels. The level of brain involvement must also be performed. With an improved assessment of the brain injuries, macro and microscopically, the relationships may become stronger.